March 10, 2003

Goestationary Operational Environmental Satellite : The GOES-8 database

Contents

1 GOES Satellites

The National Oceanic and Atmospheric Administration (NOAA) operates 2 meteorological geostationary satellites which observe 2/3 of the globe from the Atlantic ocean to the Pacific ocean. GOES satellites are located over the equator at an altitude of 35,800 km. Currently, the GOES- East satellite is GOES-8 (longitude 75 W) launched on April13rd, 1994 , and the GOES-West satellite is GOES-10 (longitude 135 W) launched the May 23rd, 1995.

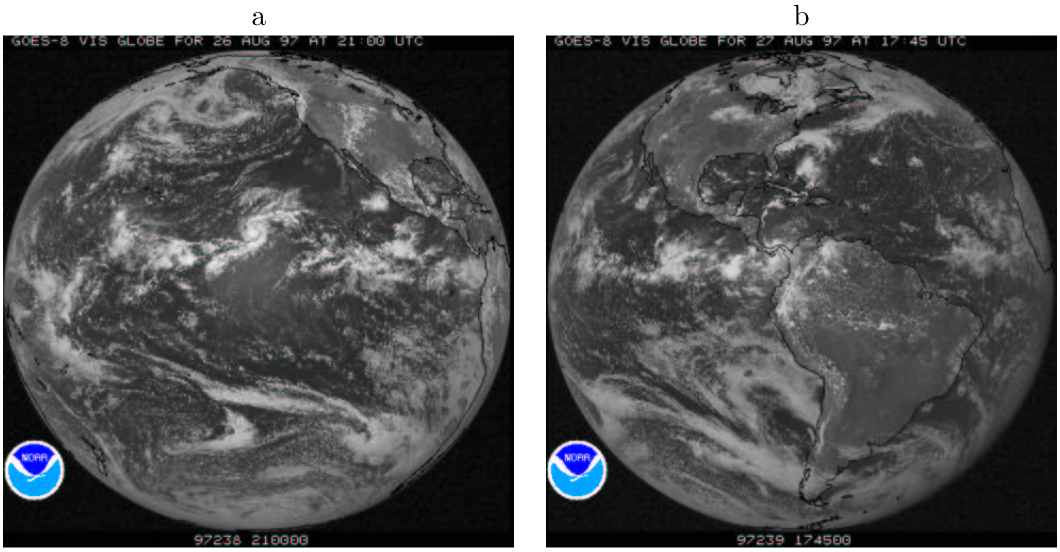

Figure 1: a : the Earth view from GOES-10 in the visible channel ; b : same but for GOES-8

2 Observation's Frequencies

GOES satellites have on board 2 kinds of apparatus, an imager and a sounder which have different sampling rates. Here is only described the features of the GOES-8 imager (see Menzel and Purdom, 1994 for more details). In routine mode, the **CONUS** is scanned by the imager each **15 minutes** , the extended Northern Hemisphere, half an hour and the full disk every 3 hours (see fig 2-a). A warning mode is also available for monitoring rapid development storms. In that case, the CONUS is scanned 8 times an hour (see fig 2-b).

3 Available Channels

The GOES-8 imager has a five-band multispectral capability with 10 bit precision and high spatial resolution. The spectral distribution of bands runs from the visible to the far infrared. Used alone or coupled, they have different applications :

- **0.52 - 0.72** μm (visible), **1 km** resolution at NADIR, useful for cloud, pollution and haze detection and severe storm identification;
- **3.78 - 4.03** μm (shortwave infrared window), **4 km** resolution at NADIR, useful for fog identification at night, discriminating between water clouds and snow or ice clouds during the daytime, detecting fires and volcanoes, and nighttime determination of sea surface temperature;

(a) (b)

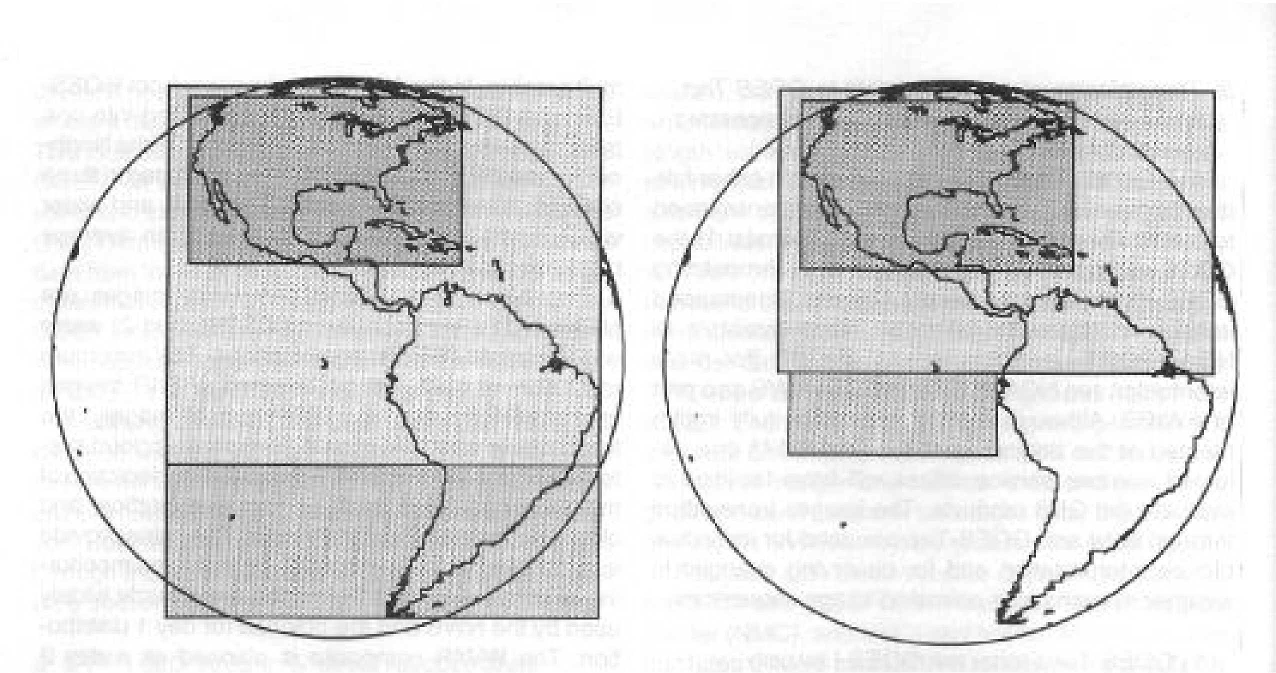

Figure 2: a : Coverage using the GOES-8 imager in routine mode : The CONUS is scanned each 15 minutes, the extended Northern Hemisphere (covering down to 20 degrees S) is scanned each 30 minutes and the full-disk coverage occurs every 3 hours. b : Coverage using the GOES-8 imager in the warning mode. Half-hour sequence proceeds as follows: Northern Hemisphere frame (covering down to the equator), CONUS frame, small Southern Hemisphere frame.

- **6.47 - 7.02** μm (upper level water vapor), **4 km** resolution at NADIR, useful for estimating regions of mid-level moisture content and advection, and tracking mid-level atmospheric motions;
- **10.2 - 11.2** μm (longwave infrared window), **4 km** resolution at NADIR, familiar to most users for cloud-drift wind and severe storm identification, and location of heavy rainfall.
- **11.5 - 12.5** μm (infrared window more sensitive to water vapor), **4 km** resolution at NADIR, useful for low-level moisture identification, sea surface temperature determination, airborne dust and volcanic ash detection.

4 Accuracy of the GOES-8 imager Measurements

4.0.1 Visible and Infrared Data

Visible data can not be calibrated in flight, thus reported visible radiation intensities are based on prelaunch calibrations and therefore, it is difficult to know the accuracy of measurements in the visible channel (see Menzel and Purdom, 1994 for more details).

IR channels are calibrated in flight. Brightness temperature errors for a scene at 300 K, are lower than 0.11 K in channel 2, 4 and 5 and 0.35 K in channel 3.

4.0.2 Geolocation Accuracy

Position of the satellite is inferred by 3 star position measurements and landmarck references. A navigation file giving the satellite orientation (roll, pitch and yaw), is available with each snapshot in each channel. However, the satellite wiggling is assumed to be sufficiently weak during a day to deserve only one navigation file. Thus, for data available under the .tiff files, geolocations of pixels are given once a day in a .nav file (see the “GOES-8 Grid “ section). Data available at LANL under the jpeg format are interpolated in fixed grid meshes that are about 4.5*4.5 or 5*5 km^2 wide. The pixel size depends on the date of the image. It has been a switch (date not really identified) of the GOES-8 coverage in June 1998. The CONUS coverage is larger after this switch.

5 GOES-8 Grid

The grids of the jpeg files are not described here because the grids are fixed and it is detailed in the “Data Under Jpeg Format” section. The data include in .tiff files are dumped from arrays of 1200x1000 pixels. Each pixel representing a different mesh area, the figure 3 displays averages of the lengths and of the mesh areas of the GOES-8 grid for the channel 4 of the imager. The highest resolution is about 4 km at NADIR. We see that the pixel size is between 8 and 16 km along both the meridians and the parallels over the major part of the CONUS. The grid size variations are the weakest along the zonal direction.

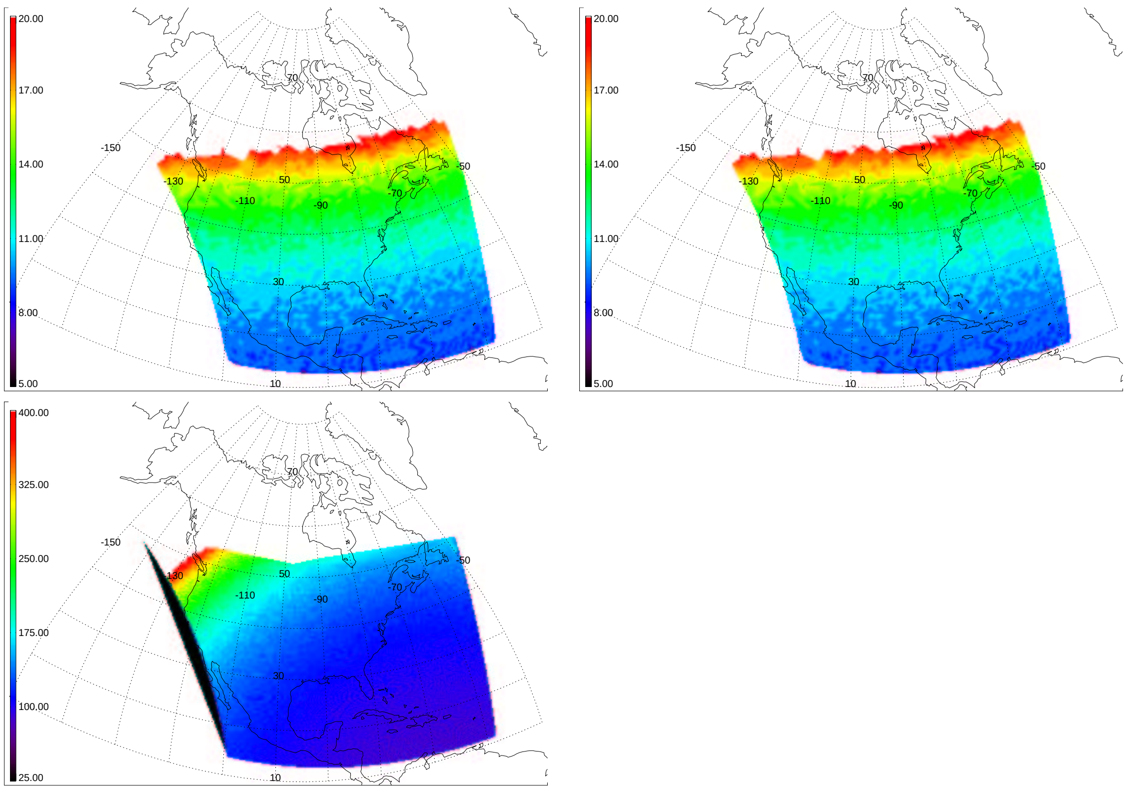

Figure 3: GOES GRID ; a : average mesh size along the meridians ; b : average mesh size along the parallels ; c : average mesh area

The figure 4 represents the standard deviation of the pixel positions for the year 1999. The deviation is more important along the parallels. However, it can be of the order or larger than the mesh size. Thus, to compare GOES-8 data to other parameters, pixel position corrections from day-to-day need to be consider.

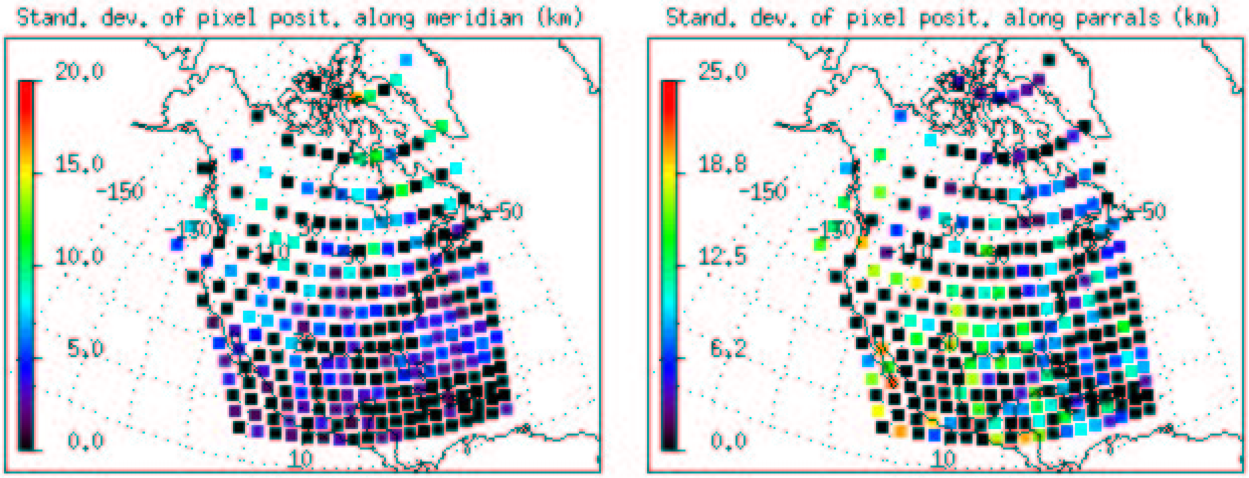

Figure 4: Left panel : standard deviation of the pixel position along the meridians ; Right panel : standard deviation of the pixel position along the parallels

5.1 Parallax Problem

The parallax problem (illustrated in figure 5) can imply wrong cloud geolocations. It is due to the approximation in GOES-8 data that the cloud and Earth altitudes are the sames from the satellite point of view. The pertinent parameters to determe the parallax displacement, are the cloud top altitude and the angular distance between the considered cloud and NADIR. The angular distance betweenn the GOES-8 NADIR and any point of the North America is represented in figure 6. The highest cloud-top surfaces are found in the tropics at angular distances from NADIR lower than 7°. For cloud-top height up to 20 km, the parallax displacement will be less than 4 km (inferred from figure 5 b). Thus, the parallax displacement is lower than the GOES-8 mesh size. The maximum angular distance meet over the North America is less than 9°. If in the region where the angular distance is maximum, cloud-top height are less than 15 km, the involved displacement distances are less than 1.4 km. Thus, the North America GOES-8 data are not concerned by the parallax problem.

6 Using Available Data

7 Available data

Table 1 shows the number of days and the percentage of images available each month of 1998 under the jpeg format.

Table 2 shows the number of days and the number of images available each month of 1999 under the tiff format. In 1998, data under the tiff format are available only in September (19 days and 47 % of images).

a b

a

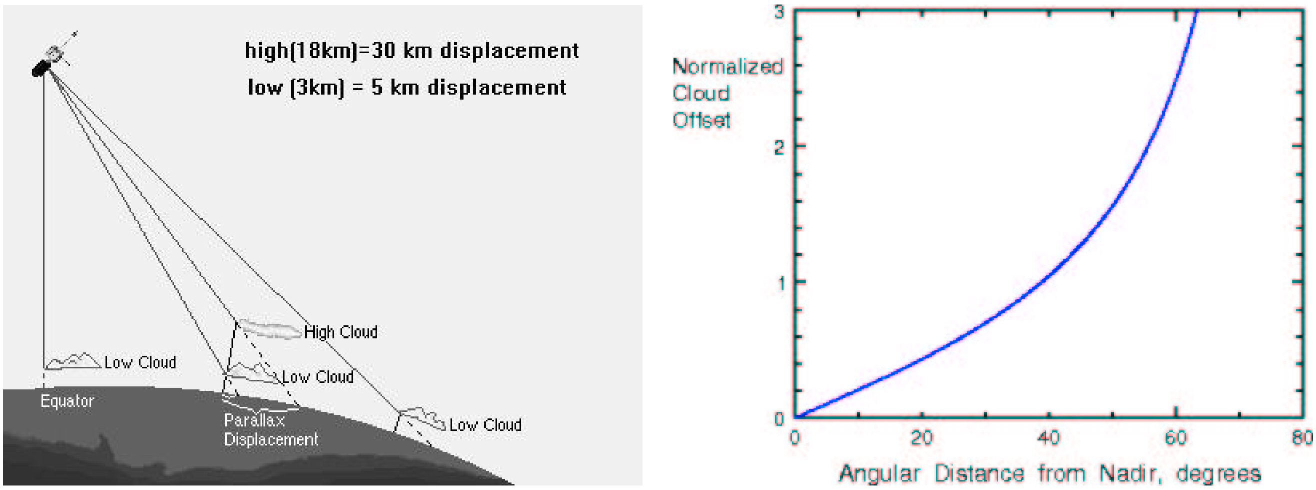

Figure 5: a : Illustration of the parallax displacement. High clouds are displaced further than low clouds. The illustration comparing high to low clouds assumes that the satellite is 52 °from the local zenith (Fig 2). In examining the above schematic it should be noted that geostationary satellites orbit at 35,800 km above the Earth surface, whereas high clouds are at most 18 km above sea level ; b : Normalized cloud offset for a geostationary satellite image, due to parallax induced cloud displacements. For a cloud at, say, 10 km altitude and an angular distance of 60 from NADIR , the offset is just the height of the cloud multiplied by the normalized offset value from the graph, i.e. 10x2.6= 26 km. The direction of the apparent offset is directly away from the satellite, along a great circle arc from the subsatellite point. From http://www-das.uwyo.edu/ geerts/cwx/notes/chap02/parallax.html

7.1 Preliminaries

Let us first define a shell variable ***S_PUBLIC*** indicating the location on the scheme of the routines presented in the following. The current value of ***S_PUBLIC*** is :
> echo $***S_PUBLIC***
> /n/toaster/u/gmolinie/PUBLIC

The *idl* programs and functions presented in the following, use other subprograms and functions stored in the '***S_PUBLIC***' subdirectories. Thus, the *idl* environmental variable "!***path***" must be set at the begining of any *idl* session. That can be done by the following command :
!***path*** = !path + ':' + EXPAND_PATH('+/n/toaster/u/gmolinie/PUBLIC/')

Moreover, in order to have relative paths to access the file containing the pixel geolocations for

Table 1: In each month of 1998, the second (respectively third) line indicates the number of day for which data are available (respectively the percentage of data available relative to a maximum number of data one can expect that is of one image each 30-minute epoch a day).

	May	June	July	August	September	October
# day	17	30	31	31	17	0
% images	33	97	85	93	46	0

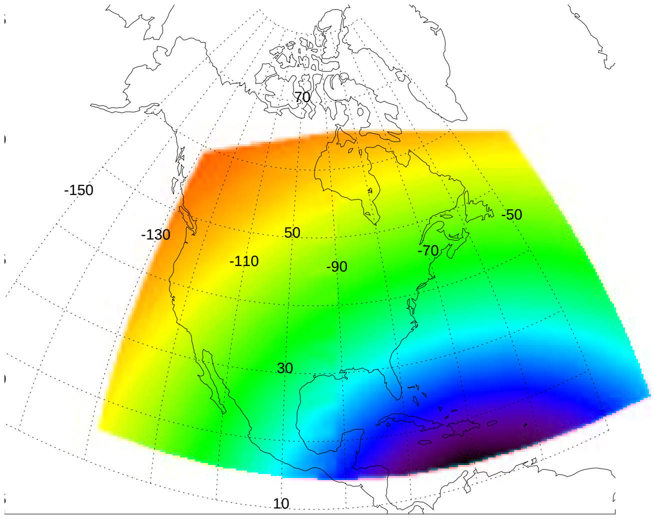

Figure 6: Angle under wich the satellite view the North America

Table 2: The second (respectively third) line indicates the percentage of day for which data are available (respectively percentage of data available relative to a maximum number of data one can expect that is of one image each 15-minute epoch a day).

	May	June	July	August	September	October
# day	27	27	31	30	30	31
% images	73	70	89	88	71	77

the different formats of GOES-8 data, the *idl* variable ***GOES_PUBLIC*** is set in the program '$*S_PUBLIC*/init_var.pro'. For an interactive *idl* session, this program must be run at the begining of the session by the *idl* command :
INIT_VAR,GOES_PUBLIC=GOES_PUBLIC

7.2 Data Under Jpeg Format

These data are available under jpeg files on the scheme in the directory :
/n/projects/forte/tmp/
Their name are of the form *sat_ir_YYMMDDHHMM.jpg*. Thus, for example the file *sat_ir_9808092152.jpg* corresponds to the scan of the 9ht of September 1998 at 21:52. These files are viewable via any image processing software. Moreover, a function called *jpeg_2_tbright.pro* allows to retrieve the brightness temperatures from the jpeg files. *JPEG_2_TBRIGHT.pro* will be described in more details later.

The program *RETRIEVE_JPEG_GEOLOC* located in "$***S_PUBLIC***/GOES/JPEG/" allows to retrieve the pixel geolocations of jpeg images. An example of call to this routine is :
RETRIEVE_JPEG_GEOLOC, ***Efilename, Flon, Flat***
Efilename =' */n/projects/forte/tmp/sat_ir_9809171322.jpg*' is the path and name of a jpeg file. The longitudes and latitudes are returned by this program in the parameters *Flon* and *Flat* that are 32 bit floating-point arrays of different size following their date of the retrieved image. As reported

in the section "Geolocation Accuracy", a switch of the covered area by GOES-8 changed at a date "switch-date" that implies changes in the jpeg file format.

7.2.1 Data Before "Date-Switch"

The jpeg files corresponding to these data are 1100x700 pixels. The pixels are about 4,45 km wide and height. The center of the image is at 39 °N latitude and 97 °W longitude. The pixel geolocations are available on the scheme in the file :
"$***S_PUBLIC***/GOES/JPEG/pixel_geolocatio_sat_ir_images_beforedate-switch.bin.xdr".

If it is necessarry to access the pixel-geolocation data for files before "date-switch" without using *RETRIEVE_JPEG_GEOLOC*, that can be done via the *idl* commands :

```
OPENR,Iurg, $
GOES_PUBLIC+'/JPEG/pixel_geolocatio_sat_ir_images_beforedate-switch.bin.xdr', $
/GET_LUN,/XDR
Flat=FLTARR(1100L*700L)
Flon=FLTARR(1100L*700L)
READU,Iurg,Flat,Flon
CLOSE,Iurg
FREE_LUN,Iurg
```

The latitude and longitude are stored in 32 bit floating-point 1D arrays, Flat and Flon respectively. The latitude *Flat[0]* and longitude *Flon[0]* correspond to the southwestern pixel (lat =22.78, lon = -120.31) and *Flat[769999]* and *Flon[769999]* the northeastern pixel (lat =48.40, lon = -63.60).

7.2.2 After "Date-Switch"

The images are 1200x896. The pixels width and height are about 5km and the center of the images is at 25 °N and 95 °W. The pixel latitudes and longitudes are given on the scheme in the text files :
"$***S_PUBLIC***/GOES/JPEG/pixel_geolocatio_sat_ir_images_lat2.txt" and
"$***S_PUBLIC***/GOES/JPEG/pixel_geolocatio_sat_ir_images_lon2.txt". Hereafter, an example to access directly to these files via *idl* commands, is given :

```
Lsizex = 1200L
Lsizey = 896L
Ftemp=FLTARR(Lsizex)
Flat = FLTARR(Lsizex, Lsizey)
Flon = FLTARR(Lsizex, Lsizey)
OPENR,Iurg1, $
GOES_PUBLIC+'/JPEG/pixel_geolocatio_sat_ir_images_lat2.txt', $
/GET_LUN
OPENR,Iurg2, $
GOES_PUBLIC+'/JPEG/pixel_geolocatio_sat_ir_images_lon2.txt', $
/GET_LUN
FOR Ii2=Lsizey-1,0,-1 DO BEGIN
READF,Iurg1,Ftemp
Flat[*,Ii2] = Ftemp[*]
READF,Iurg2, Ftemp
Flon[*,Ii2] = Ftemp[*]
ENDFOR
CLOSE,Iurg1
FREE_LUN,Iurg1
CLOSE,Iurg2
```

FREE_LUN,Iurg2

The latitudes and longitudes are stored in 32 bit floating-point 2D arrays, Flat and Flon respectively. The latitude *Flat[0,0]* and longitude *Flon[0,0]* correspond to the South-Western pixel (lat= 16.28 , lon= -126.14) and *Flat[1199,895]* and *Flon[1199,895]* to the North-Eastern pixel (lat =55.45, lon = -57.46).

7.2.3 Retrieving the Brightness Temperature from Jpeg Files

That can be done by the function : ***"JPEG_2_TBRIGHT"*** available in :
"$***S_PUBLIC***/GOES/JPEG". Brightness temperature are retrieved by an algorithm of color identification in the jpeg files. Because of the data compression used to create the jpeg files, it is possible that some pixels can not be retrieved. However, the algorithm seems the most efficient in the range -75$°C-$ -15$°C$. If a pixel can not be retrieved, in a first step a value is assigned to it after an interpolation among its successfully retrieved neighbors. If no neighbor were successfully retrieved, it is set to a temperature of 45 °C (a flag of wrong value because the maximum temperature displayed in the jpeg files is of 35 °C). The calling sequence of ***"JPEG_2_TBRIGHT"*** is :

"Fgoes_image = JPEG_2_TBRIGHT(Efilename,Sgraph=Sgraph)"
Efilename is the input name of a jpeg file ; Sgraph is a keyword allowing the graphic representation of the treated file that is send to a file entitled "example1_goes.ps" (a non-mapped image) and to "example2_goes.ps" (a mapped representation). "Fgoes_image" is a 32 bit floating point 2D array of size depending of the date of the image treated.

An example of one jpeg file conversion into brightness temperature is given in figure 7.

a b

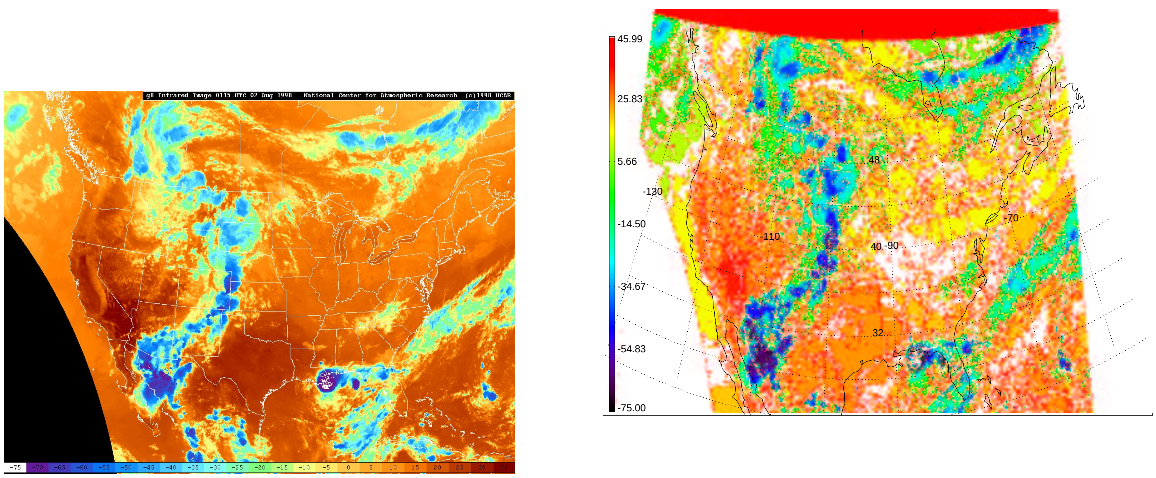

Figure 7: a : Brightness temperatures displayed from the file : sat_ir_9808020152.jpg ; b : brightness temperatures retrieved from the file sat_ir_9808020152.jpg by the function "JPEG_2_TBRIGHT".

7.3 .TIFF and .GIF files

GOES-8 data available on the scheme have been downloaded from the NCAR web site (http://www.rap.ucar.edu/weather/satellite). Data are available under three formats : tiff and gif. The gif format is used to build mosaic images no-described here. From the files suffixed .tiff, NCAR has provided us with a relationship to obtain brightness temperatures that is : $Tb = -0.5 * P + 320$ where P is the pixel values in .tiff files and Tb, the brightness temperatures in °K.

A list of the dates available can be obtained by the Unix wxls routine (see wxls -help after a shell prompt for a documentation) or the *idl* routine "wxls.pro" (see doc_library,'wxls.pro' after an *idl* prompt for more info).
Fetch the .tiff or .gif files can be done by the *idl* routine : wxfetch (doc_library,'wxfetch' for more informations). Retrieving the geolocation of .tiff or .gif pixels is easy with the routine "goes_nav.pro" and the pixels values via "wximage.pro" (both these routine are *idl* programs for which one can run "doc_library").

To retrieve the brightness temperatures of the .tiff files, one can use :
"$***S_PUBLIC***/GOES/TIFF/goes2temp.pro. This is a *idl* function callable as :
Fgoes_temp = GOES2TEMP(FLOAT(Fgoes_image)) ; where Fgoes_temp and Fgoes_image are 2 dimension arrays. Fgoes_image results from "WXIMAGE". Fgoes_temp contains the brightness temperature.

7.4 Seek a GOES-8 Image

7.4.1 From a given date

A function is available to retrieve a list of GOES-8 images around a given date and time. The function is called list_goes.pro and is available in :
$***S_PUBLIC***/GOES/
The calling sequence is :
PRINT,LIST_GOES(Nyear, Nmonth, Nday, Nhour,Nmin, $ Nmin_closer,Nmin_far,Ajpgfiles,Closest=Sclosest)

; Purpose : return a list of GOES-8 images around a date and time given by
; Nyear, Nmonth, Nday, Nhour and Nmin. The images are seek between
; the start time defined by Nhour and Nmin+Nmin_closer and end at
; the time defined by Nhour and Nmin +Nmin_far.

;Inputs :
;Ajpfiles : = 1 if use sat_ir_98*.jpg files
;Nyear = year of the image seek
;Nmonth = month of the image seek
;Nday = day of the image seek
;Nhour = hour of the image seek
;Nday = day of the image seek
;Nmin_closer = time gap (minute) after Nmin, after which the image seek is allowed
;Nmin_far = time gap (minute) after Nmin, after which the image seek is not allowed
T ;Keyword : Closest : if set return the name of the closest image to the date
;and time defined by Nyear, Nmonth, Nday, Nhour and Nmin.

Hereafter, examples of the use of the routine are shown :

```
IDL> print,LIST_GOES(1998,06,02,10,00,0,300,1)

/n/projects/forte/tmp/sat_ir_9806021107.jpg
/n/projects/forte/tmp/sat_ir_9806021137.jpg
/n/projects/forte/tmp/sat_ir_9806021007.jpg
/n/projects/forte/tmp/sat_ir_9806021037.jpg


IDL> print,LIST_GOES(1998,06,02,10,00,15,300,1)

/n/projects/forte/tmp/sat_ir_9806021107.jpg
/n/projects/forte/tmp/sat_ir_9806021137.jpg
/n/projects/forte/tmp/sat_ir_9806021037.jpg


IDL> print,LIST_GOES(1998,06,02,10,00,0,300,1,/closest)

/n/projects/forte/tmp/sat_ir_9806021007.jpg


IDL> print,LIST_GOES(1998,06,02,10,00,-15,300,1)

/n/projects/forte/tmp/sat_ir_9806020952.jpg
/n/projects/forte/tmp/sat_ir_9806021107.jpg
/n/projects/forte/tmp/sat_ir_9806021137.jpg
/n/projects/forte/tmp/sat_ir_9806021007.jpg
/n/projects/forte/tmp/sat_ir_9806021037.jpg


IDL> print,LIST_GOES(1998,06,02,10,00,-15,-300,1)

Nmin_far LT Nmin_closer : LIST_GOES failed


IDL> print,LIST_GOES(1998,06,02,23,00,0,300,1)

/n/projects/forte/tmp/sat_ir_9806030007.jpg
/n/projects/forte/tmp/sat_ir_9806030037.jpg
/n/projects/forte/tmp/sat_ir_9806022322.jpg
/n/projects/forte/tmp/sat_ir_9806022352.jpg


IDL> print,LIST_GOES(1998,06,03,0,00,-300,0,1)
/n/projects/forte/tmp/sat_ir_9806022322.jpg
/n/projects/forte/tmp/sat_ir_9806022352.jpg


IDL> print,LIST_GOES(1998,06,03,0,00,-300,0,1,/closest)
/n/projects/forte/tmp/sat_ir_9806022352.jpg
```

7.4.2 From a NLDNFD file

The discretization grid of the flash and stroke density database (NLDNFD) is based of the GOES-8 grid. The NLDNFD files are daily files. The GOES-8 file on which the grid is based is a .nav file (if it exists) else the closest jpeg file to noon and if none of the .nav of jpeg files are available, a default

.nav file is used. The function RETRIEVE_GOES_FILE provides the name of the grid based file. This function is describe in the NLDNFD documentation.

7.5 Once known the GOES-8 file.

7.5.1 Retrieve the grid

The following program return two 2D arrays containing the grid coordinates of the input GOES-8 jpeg or nav file:

```
    PRO RETRIEVE_GOES_GRID, Egoes_file,Flon_goes, Flat_goes
;
;
;+
; Purpose : Return two 2D arrays containing the GOES-8 grid latitudes
; and longitudes
;
; Inputs : Egoes_file : name of the GOES-8 (jpeg or nav) file
;
;Outputs : Flon_goes : longitudes of the GOES-8 pixels
; Flat_goes : latitudes of the GOES-8 pixels
;
;
; Calling sequences :
; retrieve_goes_grid,wxls('19990802__G08I04.nav'),Flon_goes, Flat_goes
; retrieve_goes_grid,'/n/projects/forte/tmp/sat_ir_9808022137.jpg',Flon_goes, Flat_goes
;
```

7.5.2 Retrieve the data

The following function return a 2D arrays containing the brightness temperature : RETRIEVE_GOES_DATA, Egoes_file

```
    FUNCTION RETRIEVE_GOES_DATA, Egoes_file
;
;
;+
; Purpose : Return a 2D array containing the brightness temperature
; relative to Egoes_file.
;
; Inputs : Egoes_file : name of the file download
;
;Calling sequence : help,retrieve_goes_data('nprojectsfortetmpsat_ir_9808022137.jpg')
help,retrieve_goes_data(wxls('19990802_2332_G08I04.tiff'))
```

8 A tool to plot map projections

```
;
PRO PLOT_PROJ_MAP, Flon,Flat,Pdata1,Stitle1,Eoutput_file, $
Edevice,Zoombox=Fzoombox,Pdata2=Pdata2,Stitle2=Stitle2
```

```
;+
; Purpose : map a mercartor projection of Pdata1. If Pdata2 is set,
; map the intensity of Pdata2 on which location of
; Pdata1 is superimposed by red crosses
;
; Inputs :
; Flon : Longitude of each grid point
; Flat : Latitude of each grid point
; Pdata1: Data to map
; Eoutput_file : Output file name
; Edevice: Output device ('x','ps' or 'cgm')
;
;
;
; Keywords:
; Zoombox : vector containing lonmin,latmin,lonmax,latmax
; of the region to zoom in.
; Pdata2 : background data on which Pdata1 will be superimposed
; Stitle2 : Title relative to the background data
;
;
; Calling sequence :
; RETRIEVE_GOES_GRID,WXLS('19990802__G08I04.nav'),Flon_goes, Flat_goes
; Fimage=RETRIEVE_GOES_DATA(wxls('19990802_2332_G08I04.tiff'))
; PLOT_PROJ_MAP,Flon_goes,Flat_goes,Fimage,'Plot BT(C)','Soutfile','x'
;
; RETRIEVE_GRID_FLASH,'/nh/toaster/u/gmolinie/PUBLIC/DATABASE/NLDNFD1/19990802.nldnfd',g,
f,First_scene=1,Last_scene=1
; PLOT_PROJ_MAP,g.Flon,g.Flat,f.Fncg,'Plot a BT(C)','Soutfile','x'
;
;
;
; RETRIEVE_GRID_FLASH,'/nh/toaster/u/gmolinie/PUBLIC/DATABASE/NLDNFD1/19990802.nldnfd',g,f,Fi
; PLOT_PROJ_MAP,Flon_goes,Flat_goes,F.fncg,'SD (km-2 (15min)-1','Soutfile','x'
; ,zoombox=[-110,31,-100,34],Pdata2=Fimage,Stitle2='BC (T)'
;
;
; Author : Gilles Molinie (Begun July 2nd, 2002)
```

References

Menzel, W. and J. Purdom, 1994: Introducing goes-i - the 1st of a new generation of the geostationnary operational environmental satellites. *Bull. Am. Meteor. Soc.*, **75**(5), 757–781.

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